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STUDIES ON THE EFFECT OF MULTIPLE WINDBREAKS ON WIND SPEED AT WATERER'S NURSERIES, BAGSHOT, SURREY.

AGRICULTURAL MEMORANDUM NO 890

Introduction

At one time, early in Waterer's 150 year history, nursery stock were sold with the top soil in which they had been grown; recent years have seen the development of the 'garden centre' industry and the raising of stock within containers standing on gravel beds (sometimes laid over absorbent matting to aid water up-take). These container stock at Waterer's, as at other nurseries, are prone to 'lodging' and if not righted within a few days may suffer from lack of irrigation and from distorted growth. Waterers considered it desirable to have a windbreak network to protect stock (and which would also ameliorate conditions for their staff).

Shelter siting

The Manager, Mr Clift, was interested in having a wind survey of the nursery site so that problem directions could be quantified and a suitable shelter belt network erected. Temperature data were also of interest.

Run-of-wind (2 m) readings were made twice daily in selected areas by a member of Waterer's staff. In addition spot readings of wind direction and of maximum and minimum temperatures were made at certain sites. Fig 1 illustrates a plan of Waterer's nurseries with container stock areas marked A,C,D,E,G,H,I, and J. Each area was sub-divided into 8 rectangular plots as indicated in G (for the sake of clarity the sub-division has not been represented on the other areas). Y was a stock-rearing bed. Anemometer sites are as marked (X).

Average wind directions were inferred from the S. Farnborough and Heathrow DMR data; the run of wind was only compared at the various sites when it was apparently within $\pm$ 10° to 20° over the 8-hour day or 16-hour night periods. These wind data are presented as a series of 'sectored pies' in Fig 1, (their positions on the left hand side of the figure corresponding to their sitings in A.....Y). Speeds, as a function of direction, are presented as a ratio of the 2 m S. Farnborough winds (estimated from 10 m values).

(Note: when measurements were made in I a trial paraweb wind-break was in position on the N.E. side of the areas thus affecting winds in I from a variety of directions).

Dense tree barriers on the S.W. and N.W. perimeters of the site (and not on Waterer's land) gave rise to turbulent air motions detected by smoke tests and 'dust devil' sightings to be prevalent in the path area separating Y from I, J and A.

The 'pies' show the sheltering influence of these perimeter barriers and the exposed nature of the nursery to winds from the N. and N.E. (an effect perhaps augmented by the 3° S.W. to N.E. slope of the nursery), but local gaps in the perimeter trees lead to relatively high winds from the W. or N.W. in H and Y. The sheltering influence of the tree barrier to the S.W. has diminished at G, E & C. Certainly the need for perimeter shelter to the S. and S.E. is apparent from the 'pies' of E and G. and perimeter plantings of alternate evergreen and poplar were suggested. An internal windbreak network was devised; access to plots suggested a compromise. This scheme was erected early in 1980. The equidistant, parallel nature of the multiple windbreak network, as illustrated in fig 1, lends itself to run-of-wind studies under a north-easterly wind.

Run-of-wind studies in the windbreak complex

I. Over a season, measurements were made at 1 and 2 m height at various distances

downwind of the 2 m high windbreak to the N.E. of the area I. As with the derivation of the wind 'pie' data, wind-runs under the consistent 8 or 16 hour period of north-easterly winds were analysed; results are presented graphically in Fig. 2. (H is windbreak height).
Minima in wind speed at both heights are implied somewhere in the 0 to 2.5 H downwind zone. The 2 m counter is close to the level of the top of the windbreak; apparently separation of flow and the associated vertical motion induced in the flow by the windbreak affords some shelter influence to 5 H (Plate, 1971).

IIa. On 20 March 1980 run-of-wind measurements were made at 1 m height under a north-easterly at various distances behind each wind-break (positions being indicated by e_2, d_1, d_2, i_1, i_2).

Throughout the study upwind run-of-wind information was obtained from site e_1, some 6H upwind of the first wind-break in E. Anemometers in plots e_2....i_2 were exposed at 1,2,4,6,10 and 15 H downwind of the windbreaks in E,D and I. Care was taken that the instruments were well away from local upwind obstructions such as trees and irrigation supports. Where windbreaks were of limited length (i_1 and i_2) instruments were exposed upwind of the middle of the windbreak length, avoiding 'gap' or 'end' exposures.

Recordings were made in each plot for some 30 minutes before moving the downwind instruments (e_2,...i_2) to another position. Wind runs were expressed as a fraction of the upwind run at e_1 ; results are presented graphically in Figs 3 and 4, n_i referring to the run in e_2...i_2.

IIb. A study was made with anemometers simultaneously in d_2, d_1 giving the upwind data. Results are presented in Fig 5.

III. Wind runs were recorded in one of the pathway gaps in I. Sets of two anemometers were placed downwind of the windbreak, one in the gap, one centrally behind the windbreak at downwind distances of 0*, 1,2, 6 and 10 H (* an anemometer in the gap was necessarily compared with the sheltered one a little downwind).

The ratios of 'gap' to 'sheltered' runs for corresponding distances downwind are illustrated in Fig. 6.

IV. Temperature studies

Throughout the initial studies on shelter siting maximum and minimum temperatures were recorded at 1 m over gravel at each of the sites. Results for minimum temperatures (°C) are summarised as follows:-

With reference to D

	G 0.2 warmer	H 0.2 colder	
E 0.4 warmer	D reference	I 0.2 colder	
	C 0.2 warmer	J equal	
		A	Y 0.9 colder

NE SW

In view of the downward slope of the nursery from SW to NE the fact that the SW part of the nursery is colder than the lower lying NE area is surprising.

Discussion

A single wind-break in a wide plain presents only a transitory disturbance to the wind flow. An extensive system of wind protection, according to Kaiser (1959), leads to a new equilibrium of flow due to the greater surface roughness. He suggests that transition to a new air flow equilibrium takes place by a series of oscillations the transition zone (over which shearing stress is modified) adapting itself to the degree of increased roughness over several kilometres; clearly no new equilibrium state is likely to have resulted from the roughness elements in this study by the time i_2 has been reached.

Other studies on multiple windbreaks have been done by Naegeli (1943) on two belts 20 and 23 m high separated by 550 m. The wind reduction windward of the first belt started at about 7H, the full 'open-wind' not being regained between belts, the maximum being 80% some 6.5H windward of the second belt. A wind minimum of 25% lies 2 to 3H behind the first (denser) belt and is 40% at 3H behind the more open one, ie no influence of the belts on one another which is in opposition to the view by Rohweder (1952) and others that wind reduction is successively increased.

In Naegeli (1946) measurements behind 3 and 4 belts of $5\frac{1}{2}$ m height and 20 m width, irregular wind reductions were observed at individual belts but an accumulative effect was not noticeable. Systematic experiments are not easily performed (except in a wind tunnel with all the attendant scaling problems and lack of reality as regard to turbulence (Mulhearn & Bradley, (1977) Iqbal et al, (1977)). Kaiser (1959) with 12 maize belts 3 m high and 4H apart found the wind reduction behind the second belt less, and before the third belt to be greater, than between belts 1 & 2.

Figs 3,4 illustrate that although at about 10H and beyond wind reduction behind each wind break is roughly in accordance with a 'successive' reduction (ie least behind e_2 greatest behind i_2, the order being e_2, d_2, d_1, i_1, i_2) the picture is more confused close in; although i_2 shows the greatest reduction, e_2 is ranked second. Both d_1 and d_2 show a minimum in wind speed, (d_1 at 4H, d_2 closer in) this pattern was not apparent at the other sites at least as close as 2H and fig 5 shows that in D, d_2 anyway had a minimum which must have been between 0 and 1H.

According to WMO Tech Note 59 (Windbreaks and Shelterbelts) the question of the best interval for parallel windbreaks depends on shape, density and height of belt, frequency of wind direction, type of crop, nature of soil and the period for which protection is required. In the special case of cropping in orchards van Rhee (1958) showed maximum cropping at between 4 and 8H; Starr (1978) observed considerable wind reduction in an orchard within a poplar network.

Figs 2, 3, 4 and 5 confirm the generally held belief that a practical compromise for spacing of parallel windbreaks is 10 to 15H; the figures do not all agree that the wind minimum is at about 4H.

Gaps

Naegeli (1953) experimented with reed mats, leaving a gap of 10 m (about 4.5H) between adjacent ones. In this opening winds rose above 120% of the free value, the increase beginning at 5H windward and being noticeable up to 14 to 18H downwind.

The Waterer's studies indicate that although the wind in the (2 m) gap between the paraweb windbreaks and at 1H downwind was $2\frac{1}{2}$ to 3 times the sheltered wind just downwind (1H) the gap wind swiftly took on the speed of the sheltered wind (Fig 6). By 2H downwind and beyond, the two (gap and sheltered) anemometers at the same distance downwind measured similar winds.

The directionally fluctuating nature of the wind implies that the length to gap ratio of 7.5 at Waterers effectively reduces gap effects in a parallel windbreak system; larger gap/shelter ratios might be anticipated in a wind tunnel study with constant air flow direction.

Any comments or suggestions on this paper should be referred to the author.

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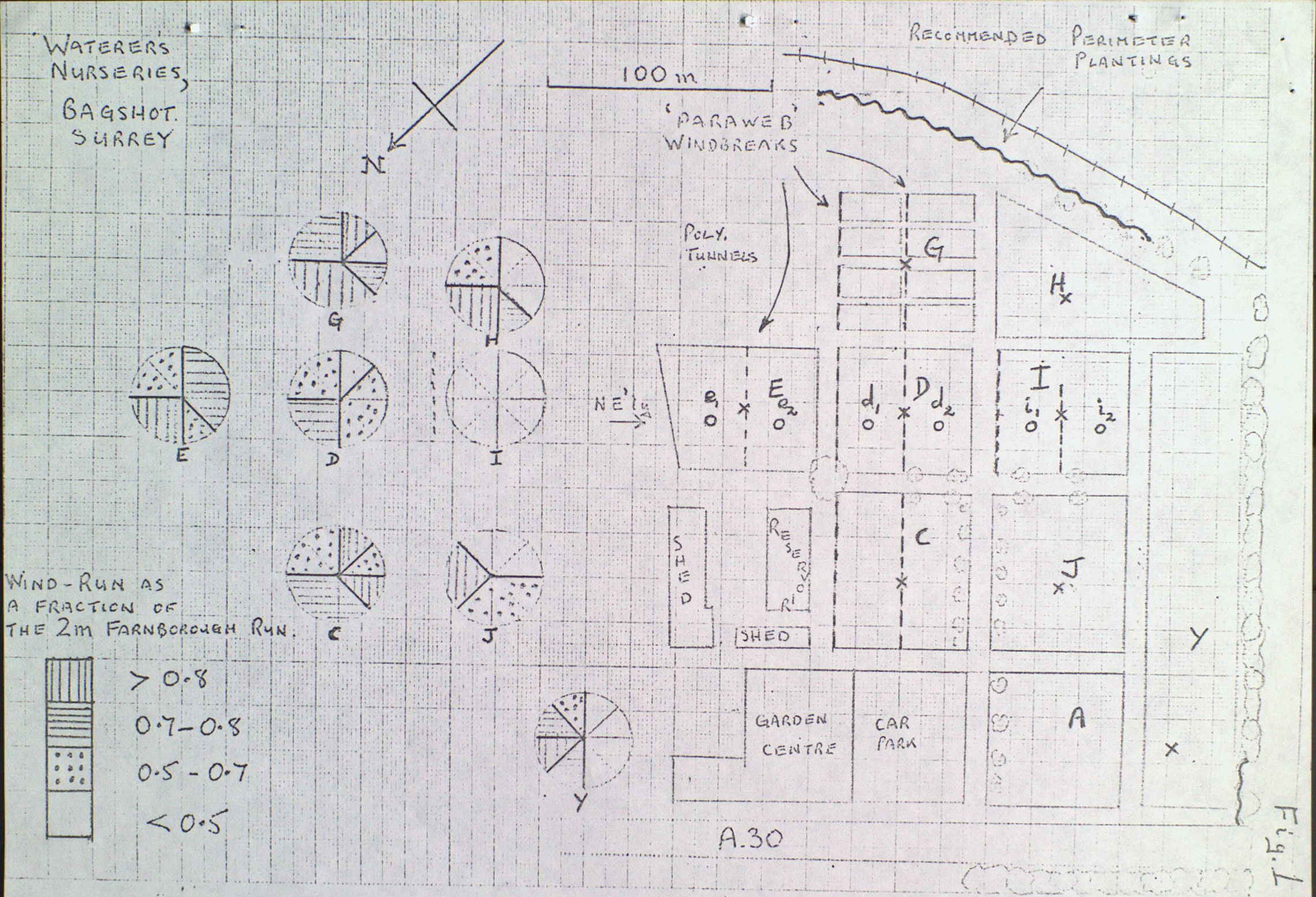

WATERERS NURSERIES, BAGSHOT. SURREY
N
100 m
'PARAWEB' WINDBREAKS
RECOMMENDED PERIMETER PLANTINGS
POLY. TUNNELS
G
H
E
D
I
C
J
Y
NE
SHED
RESERVOIR
SHED
GARDEN CENTRE
CAR PARK
A
WIND-RUN AS A FRACTION OF THE 2m FARNBOROUGH RUN.
> 0·8
0·7–0·8
0·5 - 0·7
< 0·5
A.30
Fig. 1

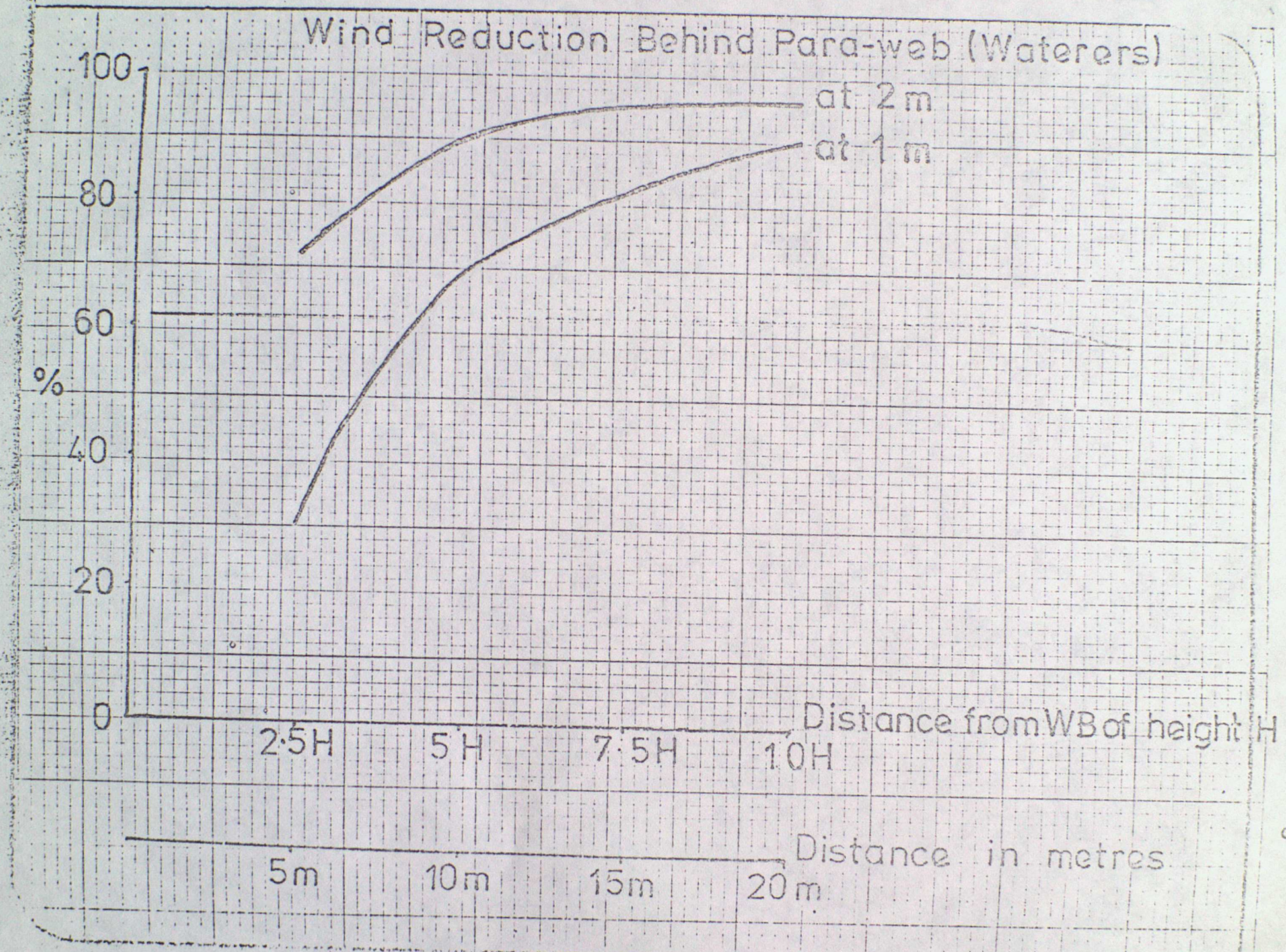
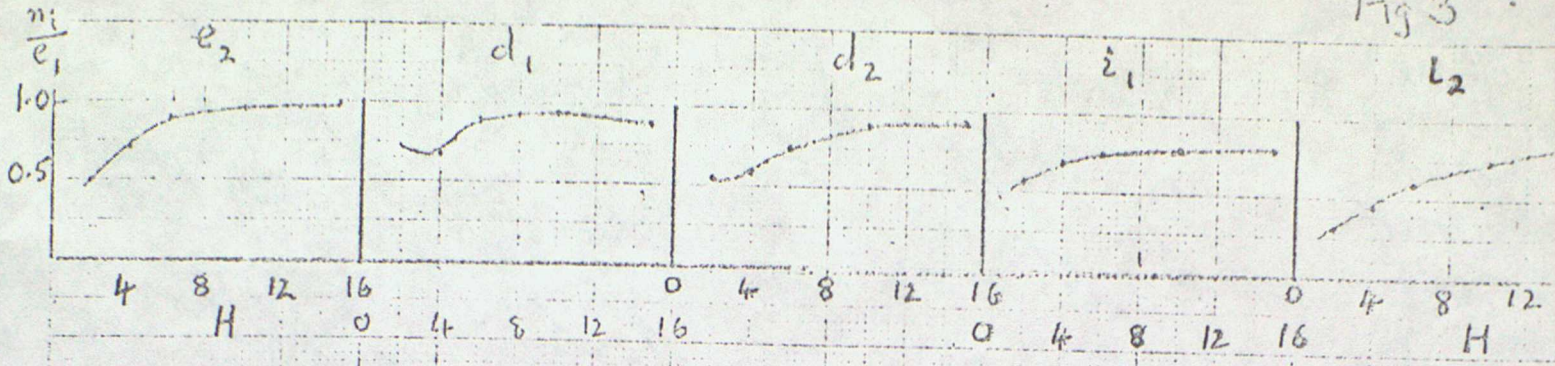

Wind Reduction Behind Para-web (Waterers)
at 2 m
at 1 m
100
80
60
%
40
20
0
2·5H
5 H
7·5H
10H
Distance from WB of height H
5m
10m
15m
20 m
Distance in metres

Fig. 2.

Fig 3



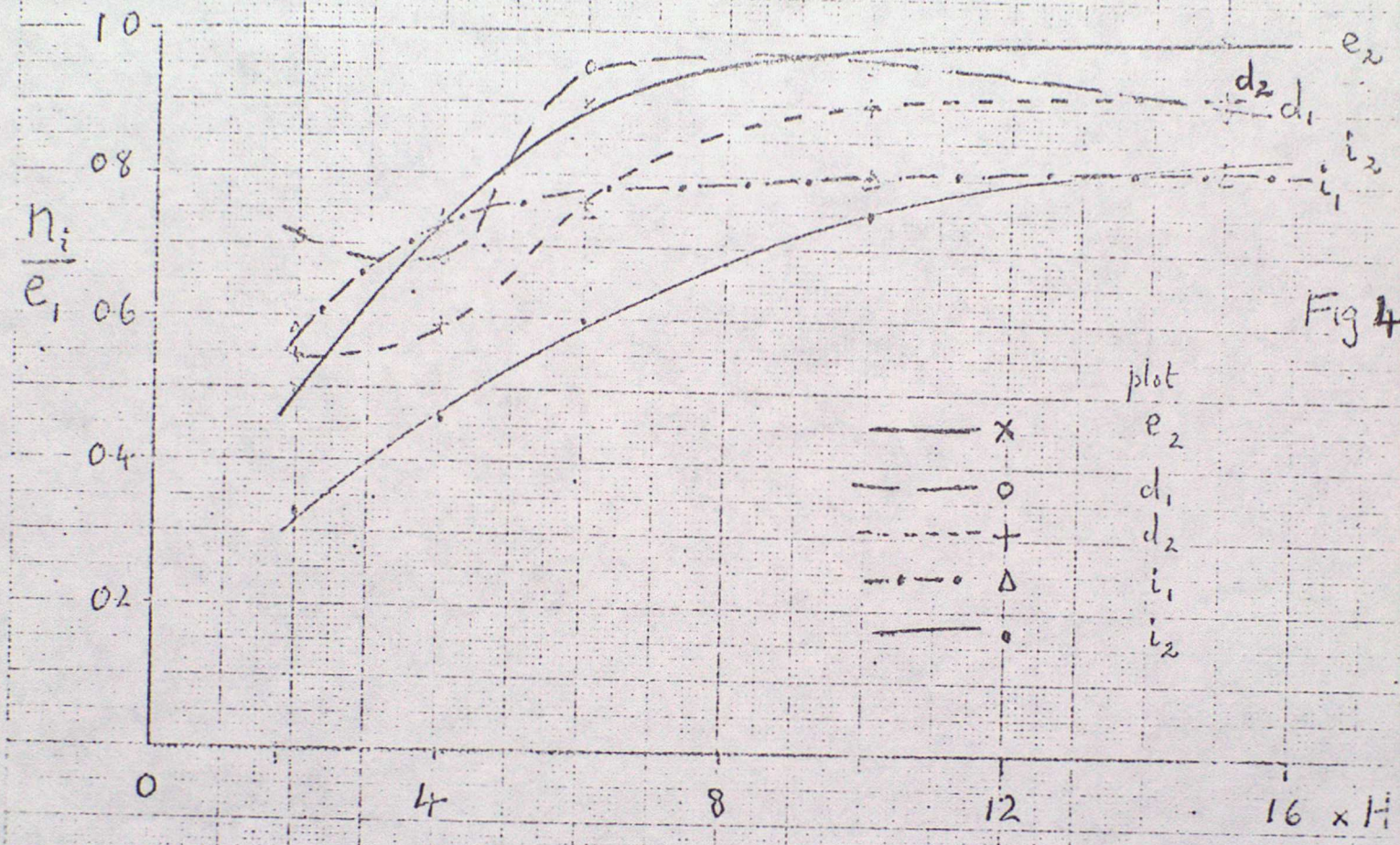


Fig 4

Fig. 5

Fig. 6